Amendments to the Specification:

Amendment to the Title:

Please amend the title to read "A FUEL CELL SYSTEM AND METHOD OF OPERATION TO REDUCE PARASITIC LOAD OF FUEL CELL PERIPHERALS"

Please replace paragraph **[0003]**, with the following amended paragraph:

[0003] Proton exchange membranes require a wet surface to facilitate the conduction of protons from the anode to the cathode, and otherwise to maintain the membranes electrically conductive. It has been suggested that each proton that moves through the membrane drags at least two or three water molecules with it (U.S. Patent 5,996,976). U.S. Patent 5,786,104 describes in qualitative terms a mechanism termed "water pumping", involving the transport of cations (protons) with water molecules through the membrane. As the current density increases, the number of water molecules moved through the membrane also increases. Eventually the flux of water being ~~pull d~~pulled through the membrane by the proton flux exceeds the rate at which water is replenished by diffusion. At this point the membrane begins to dry out, at least on the anode side, and its internal resistance increases. It will be appreciated that this mechanism drives water to the cathode side, and additionally the water created by reaction is formed at the cathode side. Nonetheless, it is possible for the flow of gas across the cathode side to be sufficient to remove this water, resulting in drying out on the cathode side as well. To maintain membrane conductivity, the surface of the membrane must remain moist at all times. Therefore, to ensure adequate efficiency, the process gases must be, on entering the fuel cell, at an appropriate humidity and at a suitable temperature for keeping the membrane moist. The range for suitable humidities and temperatures will depend on system requirements.

Please replace the following title at the beginning of page 3 with the following amended title:

~~Summary f th Invention~~Summary of the Invention

Please replace paragraph **[0009]**, with the following amended paragraph:

[0009] In accordance with an aspect of the present invention, there is provided a fuel cell system comprising; (a) fuel cell for driving a load; (b) at least one fuel cell peripheral; (c) a measurement means for determining at least one fuel cell operation characteristic indicative of the power output of the fuel cell and having a fuel cell operation characteristic spectrum; and (d) at least one controller for controlling the operation of the at least one fuel cell peripheral based on the at least one fuel cell operation characteristic;

wherein said at least one fuel cell peripheral comprises at least one of a coolant recirculation pump, a hydrogen recirculation pump, and a hydrogen purging means;

wherein each fuel cell operation characteristic spectrum is divided into at least two ranges indicative of at least two corresponding ranges of power output, and the controller is adapted to control said at least one fuel cell peripheral to provide a respective operational characteristic for said at least one fuel cell peripheral for each range.

~~(a) a fuel cell for driving a load; (b) at least one fuel cell peripheral; (c) a measurement means for determining at least one fuel cell operation characteristic; and, (d) at least one controller for controlling the operation of at least one fuel cell peripheral based on the at least one fuel cell operation characteristic. The spectrum of the at least one fuel cell operation characteristic is divided into at least two ranges, and the controller is adapted to control the at least one fuel cell peripheral to provide a respective operational characteristic for the at least one fuel cell peripheral for each range.~~

Please replace paragraph **[0010]**, with the following amended paragraph:

[0010] In accordance with a second aspect of the present invention, there is provided a method of operating a fuel cell system comprising a fuel cell, and at least one fuel cell peripheral. The method comprises a) providing at least one of a coolant recirculation pump, a hydrogen recirculation pump and a hydrogen purging means as the at least one fuel cell peripheral; b) connecting a load to the fuel cell system and providing a drive current from the fuel cell system to drive the load; c) measuring at least one fuel cell operation characteristic; and d) controlling an operational characteristic of the at least one fuel cell peripheral based on the at least one fuel cell characteristic, and for at least two different ranges of the fuel cell operation characteristic, providing a respective operational characteristic for said at least one fuel cell peripheral.
~~(a) connecting a load to the fuel cell system and providing a drive current from the fuel cell system to drive the load; (b) measuring at least one fuel cell operation characteristic; and (c) controlling an operational characteristic of the at least one fuel cell peripheral based on the at least one fuel cell characteristic, and for at least two different ranges of the fuel cell operation characteristic, providing a respective operational characteristic for the at least one fuel cell peripheral.~~

Please replace paragraph **[0020]**, with the following amended paragraph:

[0020] The fuel supply line 20 is connected to a fuel source 21 for supplying hydrogen to the anode of the fuel cell 12. A hydrogen humidifier 90 is disposed in the fuel supply line 20 upstream from the fuel cell 12 and an anode water separator 95 is disposed between the hydrogen humidifier 90 and the fuel cell 12. The oxidant supply line 30 is connected to an oxidant source 31, e.g. ambient air, for supplying air to the cathode of the fuel cell 12. A regenerative dryer 80 is disposed in the oxidant supply line 30 upstream of the fuel cell 12 and also in the cathode recirculation line 40. A cathode water separator 85 is disposed between the regenerative dryer 80 and the fuel cell 12. The regenerative dryer 80 can comprise porous materials with a desiccant and may be any commercially available dryer suitable for fuel cell system. The regenerative dryer 80

has a switch means to allow gases from the oxidant supply line 30 and the oxidant recirculation line 40 to alternately pass through the regenerative dryer 80 to exchange heat and humidity. Dry ambient air enters ~~th~~ the oxidant supply line 30 and first passes through an air filter 32 that filters out the impurity particles. A blower 35 is disposed upstream of ~~th~~ the regenerative dryer 80, to draw air from the air filter 32 and to pass the air through the regenerative dryer 80.

Please replace paragraph **[0022]**, with the following amended paragraph:

[0022] From the hydrogen humidifier 90, the fuel cell cathode exhaust stream continues to flow along the recirculation line 40 and passes through the regenerative dryer 80, as mentioned above. As the humid cathode exhaust passes through the regenerative dryer 80, the heat and moisture is retained in the porous paper or fiber material of the regenerative dryer 80. After the porous paper or fiber material of the regenerative dryer 80 has been humidified by the humid cathode exhaust pressing therethrough, the switch means of the regenerative dryer 80 switches the connection of the regenerative dryer 80 from the cathode exhaust stream to the incoming air stream, and the humidity retained in the porous paper or fiber material of the regenerative dryer 80 is then transferred to the incoming dry air stream passing through the regenerative dryer 80 in the oxidant supply line 30. Concurrently the cathode exhaust stream continues to flow along the recirculation line 40 to an exhaust water separator 100 in which the ~~xcess~~ excess water, again in liquid form, that has not been transferred to the incoming hydrogen and air ~~str ams~~streams is separated from the exhaust stream. Then the exhaust stream is discharged to the environment along a discharge line 50.

Please replace paragraph **[0025]**, with the following amended paragraph:

[0025] Fuel cell anode exhaust comprising excess hydrogen and water is recirculated by a recirculation pump 64 along the anode recirculation line 60 connected to the anode outlet of the fuel cell 12. The anode recirculation line 60 connects to the fuel supply line 20 at a first joint 62 upstream from the anode water separator 95. The

recirculation of the excess hydrogen together with water vapor not only permits utilization of hydrogen to the greatest possible extent and prevents liquid water from blocking hydrogen reactant delivery to the reactant sites, but also achieves self-humidification of the fuel stream since the water vapor from the recirculated hydrogen humidifies the incoming hydrogen from the hydrogen humidifier 90. This is highly desirable since this arrangement offers more flexibility in the choice of hydrogen humidifier 90 as the humidifier 90 does not then need to be a highly efficient one in the ~~pres nt~~present system. By appropriately selecting the ~~hydrog n~~hydrogen recirculation flow rate, the required ~~fficiency~~efficiency of the hydrogen humidifier 90 can ~~b~~ be minimized. For example, supposing the fuel cell 12 needs one unit of hydrogen, hydrogen can be supplied from the hydrogen source in the amount of three units with two units of excess hydrogen recirculated together with water vapor. The speed of recirculation pump 64 may be varied to adjust the portion of recirculated hydrogen in the mixture of hydrogen downstream from the first joint 62. The selection of stoichiometry and recirculation pump 64 speed may eventually lead to the omission of the hydrogen humidifier 90.

Please replace paragraph **[0027]**, with the following amended paragraph:

[0027] The hydrogen purge line 70 runs from the branch point 74 to a second joint 92 at which it joins the cathode exhaust recirculation line 40. Then the mixture of purged hydrogen and the cathode exhaust from the regenerative dryer 80 passes through the exhaust water separator 100. Water is condensed in the water separator 100 and the remaining gas mixture is discharged to the environment along the discharge line 50. Alternatively, either the cathode exhaust recirculation line 40 or the purge line 70 can be connected directly into the water separator 100. It is also known to those skilled in the art that the purged hydrogen or the cathode exhaust from the regenerative dryer 80 can ~~b~~ be separately discharged without condensing water therefrom.

Please replace paragraph **[0028]**, with the following amended paragraph:

[0028] Preferably, water ~~s paratcd~~separated by the anode water separator 95, cathode water separator 85, and the exhaust water separator 100 are not discharged, but rather the water is recovered respectively along anode inlet drain line 96, cathode inlet drain line 84 and discharge drain line 94 to a product water tank, for use in various processes.

Please replace paragraph **[0031]**, with the following amended paragraph:

[0031] Referring to Figure 2, there is illustrated in a schematic flow diagram an alternative fuel cell gas and water management system. In Figure 2, components similar to the components illustrated in Figure 1 are indicated using the same reference numerals, and for simplicity and brevity, the description of these components is not repeated. As shown in Figure 2, a heat exchanger 15 is provided in the first cooling loop 14 to maintain the temperature of the coolant in the first cooling loop 14 at a desired level. In this case, the second cooling loop 16 is omitted. It is to be understood that the heat exchanger 15 in Figure 1 could also be an isolation, brazed plate heat exchanger disposed in an ~~"op n"~~ "open" cooling loop, as may be desired in some applications. That is to say, the second cooling loop 16 can be an open cooling loop in which coolant is drawn from and returned to a coolant reservoir, such as atmosphere, sea, etc.

Please replace paragraph **[0033]**, with the following amended paragraph:

[0033] Preferably, a flow regulating device 22 is disposed in the fuel supply line 20 upstream from the hydrogen humidifier 90. The flow regulating device or valve 22 permits the flow of hydrogen from the hydrogen source 21 to the fuel cell 12 in response to the pressure drop in the fuel supply line 20. The flow regulating device 22 may be a forward pressure regulator having a set point ~~and~~ that permits hydrogen to be supplied to the fuel cell 12 when the pressure in the fuel supply line 20 is below the set point due to the hydrogen consumption in the fuel cell 12. This forward pressure regulator avoids

the need for an expensive mass flow controller and provides more rapid response and accurate flow control.

Please replace paragraph **[0035]**, with the following amended paragraph:

[0035] It is to be understood that although in this embodiment, the cathode exhaust is used to first humidify ~~th~~ the incoming hydrogen and then the incoming air, this order is not essential. Instead, the cathode exhaust may be used to first humidify the incoming air and then the incoming ~~hydrog n~~hydrogen. Alternatively, as shown in Figure 5a, the hydrogen humidifier 90 and the regenerative dryer 80 may be placed in parallel instead of series in the cathode exhaust recirculation line 60, so that the humidification of both hydrogen and air occurs simultaneously. Optionally, depending on the operation condition of the fuel cell 12, when the serial humidification is employed, a bypass line 82 may be further provided, as shown in Figure 5b, to bypass the hydrogen humidifier 90 so that a portion of the cathode exhaust stream flows to the regenerative dryer 80 without passing through the hydrogen humidifier.

Please replace paragraph **[0036]**, with the following amended paragraph:

[0036] However, in practice it may be preferable to humidify the hydrogen stream first since the anode dew point temperature is desired to be higher than the cathode dew point temperature because water is naturally transferred from the anode to the cathode in the fuel cell 12. The desired relative humidity of hydrogen is also often higher than that of air in the fuel cell 12 so that the fuel cell 12 will not be flooded. Therefore, it is preferable to use the cathode exhaust stream to exchange heat and humidity with incoming hydrogen stream first.

Please replace paragraph **[0038]**, with the following amended paragraph:

[0038] It can be appreciated that it is not essential to over saturate process gases, condense water out to obtain 100% relative humidity and then deliver the process gases at certain temperature to get desired relative humidity before they enter

the fuel cell 12, as in ~~the applicant's co-pending U.S. Patent Application No. 09/801,916~~assignee's U.S. Patent No. 6,787,254. The present system is applicable to ~~ful~~ fuel cell systems ~~wher~~ where fuel and oxidant stream either have or do not have 100% relative humidity. An anode dew point heat exchanger and a cathode dew point ~~hat~~ heat exchanger may be provided to control the humidity of fuel and oxidant when the fuel cell 12 is not operable with fuel or oxidant having 100% relative humidity. However, this totally depends on the characteristic of the fuel cell 12, such as the operating condition of the proton exchange membrane. It can be appreciated that it is not essential to over saturate process gases, condense water out to obtain 100% relative humidity and then deliver the process gases at certain temperature to get desired relative humidity before they enter the fuel cell 12, as in the applicant's co-pending U.S. Patent Application No. 09/801,916. The present system is applicable to fuel cell systems where fuel and oxidant stream either have or do not have 100% relative humidity. An anode dew point heat exchanger and a cathode dew point heat exchanger may be provided to control the humidity of fuel and oxidant when the fuel cell 12 is not operable with fuel or oxidant having 100% relative humidity. However, this totally depends on the characteristic of the fuel cell 12, such as the operating condition of the proton exchange membrane.

Please replace paragraph **[0042]**, with the following amended paragraph:

[0042] Regardless of the pressure under which the fuel cell system is operating, it is often ~~preferabl~~ preferable to balance the pressure of both fuel stream and oxidant stream supplied to the fuel cell 12. This ensures no significant pressure gradient exists within the fuel cell 12 and hence prevents damage of the fuel cell and prevents flow of reactants and coolants in undesired directions caused by pressure gradient. In addition, this also ensures proper stoichiometry of fuel and oxidant is supplied to the fuel cell 12 for reaction.

Please replace paragraph **[0043]**, with the following amended paragraph:

[0043] In the fuel cell systems illustrated, this is done by providing a balance pressure regulator 22' and a pressure balancing line 25 between the fuel supply line 20 and the oxidant supply line 30, as shown in Figure 6. The pressure balancing line 25 fluidly connects the balance pressure regulator 22' disposed in the fuel supply line 20 upstream of the hydrogen humidifier 90, and a third joint 102 in the oxidant supply line 30 upstream of the regenerative dryer 80. The balance pressure regulator 22' can still be a forward pressure regulator. However, it has to be adapted to work with two fluid streams and serves to balance the pressure between the two fluid streams. An example of this balance pressure regulator 22' is disclosed in ~~the applicant's co-pending U.S Patent Application No. 09/961,092~~assignee's U.S. Patent No. 6,866,061, incorporated herein by reference. Generally, such balance pressure regulator 22' regulates the hydrogen flow in response to the pressure of air stream introduced by the pressure balancing line 25, and achieves mechanical balance until the pressure of hydrogen flow is regulated to be equal to that of the air flow.

Please replace paragraph **[0047]**, with the following amended paragraph:

[0047] In conventional fuel cell systems, these fuel cell peripherals tend to run at a relatively constant speed independent of the power output of the fuel cell, even when the load current drawn from the fuel cell 12 or load demand for the fuel cell 12 is relatively low. Therefore more energy is consumed by these peripherals than what is actually needed. The present invention aims to alleviate this problem. In the present invention, the overall operation spectrum of the fuel cell 12 is broken down into several ranges and the operation of the fuel cell peripherals is controlled to operate at different levels, at different operational characteristics, for each range, i.e. there is a fuel cell operation characteristic spectrum indicative of the power level and having at least two ranges, that are correlated to respective operational characteristics of at least one fuel cell peripheral. For example, when the load draws a small current from the fuel cell 12, which means the demand for energy is low, the coolant pump 13 and the hydrogen recirculation pump 64 run at lower speeds to minimize energy consumption and the

hydrogen purge valve 72 purges hydrogen at a lower frequency to minimize fuel waste. An example is shown in Table 1 below, i.e. the valve 72 opens once every ten ~~seonds~~ seconds ~~whn~~ when the current density is in the lowest range 0-0.1A/cm^2, and once every 0-2 seconds for the highest range of greater than 0.6 amp/cm^2.

Table 1

Current Density (A/cm^2)	0-0.1	0.1-0.2	0.2-0.4	0.4-0.6	>0.6
H_2 purge frequency	1/10 seconds	1/2 seconds	1/0.6 seconds	1/0.4 seconds	1/0.2 seconds
H2 recirculation frequency	5 seconds /2minutes	10 seconds /2minutes	5 seconds/ 15seconds	5 seconds /8 seconds	full

Please replace paragraph **[0055]**, with the following amended paragraph:

[0055] While the above description constitutes the preferred embodiments, it will be appreciated that the present invention is susceptible to modification and change without departing from the fair meaning of the proper scope of the accompanying claims. For example, instead of splitting the fuel cell operation spectrum into ranges, this spectrum may be treated as a continuum and the operation of the fuel cell peripherals continuously varied depending upon the point in this continuum at which the fuel cell is presently operating. In addition, the present invention might have applicability in various types of fuel cells, which include but are not limited to, solid oxide, alkaline, molton-carbonate, and phosphoric acid. In particular, the present invention may be applied to fuel cells, which operate at much higher temperatures. As will be appreciated by those skilled in the art, the requirement for humidification is very dependent on the electrolyte used and also the ~~temp rature~~temperature and pressure of operation of the fuel cell. Accordingly, it will be understood that the ~~pres nt~~present invention may not be applicable to many types of fuel cells.